In a typical photoconductive television camera tube arrangement as at present known, an optical image is projected on to the photoconductive target of the tube, causing the target to become conductive. The signal side of the target is connected through a high impedance to a positive potential. When the target becomes conductive the potential of the rear of each target element rises towards the positive potential in proportion to the light falling on the target element. A beam of electrons scans the rear of the target discharging the target elements in turn. Since the electrons are accelerated from near rest at the cathode potential, typically zero volts, the electrons will land on a particular target element and discharge it to approximately cathode potential after which no further electrons will land on the element until the next scan.

The action of discharging produces a signal current in the signal electrode that is proportional to the light falling on the target element being scanned. The electron beam is normally arranged to be capable of discharging an overload signal that is twice the peak white signal. If a larger overload is present the beam is unable to discharge the target element completely during one scan, so the mean potential of the target element rises towards the potential of the signal side of the target. This abnormally high potential deflects the electron beam towards the positive overload when the beam is scanning elements adjacent to the overload. This is called beam pulling and increases the apparent size of the area of the overload. The increase in size is called blooming.

If the position of the overload moves across the target, due to movement of the camera or of the bright object being viewed, the beam is unable to discharge the target elements immediately after the overload has moved to another part of the target. It may take several scans to completely discharge the target elements and this results in a white tail following the moving bright image, called a comet tail.

An H.O.P. (Highlight Overload Protection) or A.C.T. (Anti Comet Tail) type of camera tube uses an entirely different electrode structure to a normal (non H.O.P.) tube. In an H.O.P. or A.C.T. tube the beam is focused inside the gun assembly forming a beam crossover where the cross sectional area of the beam is very small. After the crossover, the beam is divergent and only a small part of the beam passes through a hole in the centre of the final electrode of the gun.

THE COMPACT DISC MANUFACTURING PROCESS

The Compact Disc has become ubiquitous since its introduction in the early 1980s.

Yet, for most people, how a CD is made remains a mystery. At duplication.ca, we have chosen an experienced, ISO9002-certified CD manufacturing partner that has been in the business since the early days of the Compact Disc. The plant is capable of producing hundreds of thousands of CDs per day. The CD manufacturing process includes eight stages of production. The first stage applies only to CD-ROM production, while the remaining steps are dedicated to both CD-Audio and CD-ROM.

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1. Premastering

First, we ensure the CD-ROM content provided by our customers meets the proper ISO standards when it is organized on the disc. This is an essential step to guarantee quality for professionals who require precise, high quality data reproduction that is backed by ISO certification.

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2. Mastering

Then we create a glass master covered with a photosensitive layer and engrave all our customer's information on it with a laser light. To help fight against piracy on behalf of our customers, the plant engraves its International Federation of the Phonographic Industry (IFPI) number on every glass disc it produces. Following that, a fine silver coating is applied to the glass master's surface by a process known as vacuum evaporation.

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3. Electroplating

The glass master is then transformed into a "mould" which is used to press discs. This is achieved by adding a layer of nickel on the glass master by means of electrolysis. The nickel layer is then separated from the glass base to recover the negative of the CD. The result is what is called the stamper. Other masters can be produced by repeating the electrolysis phase.

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4. Pressing

With the mould ready, CDs can now be replicated. Liquefied polycarbonate is then injected into the mould

and, after only a few seconds of pressing, a compact disc containing all the data is quickly created.

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5. Metallization

In order for the CD to be readable, it must be covered with a micro thin layer of aluminum which is vacuum laid. The aluminum surface acts as a mirror to reflect the laser light back so information can be read.

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6. Varnishing

To protect the CD and its information from harm — scratching, bending, or dropping it — the disc is covered with a layer of varnish. The lacquer envelops the aluminum and seals it from the elements. The disc is then ready for printing.

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7. Label printing

The final touch comes with the printing of the label right on the disc, either by a silk screen or offset process and with up to six colors. The result is a clean, polished appearance.

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8. Packaging

The CD is automatically packaged and prepared for shipping. We are committed to providing customers with the highest quality printing services and the most complete selection of packaging solutions in the industry. We know the importance of choosing packaging that has maximum customer impact, and offer a variety of options from cost-saving automated packaging to custom-made solutions.

Mastering

Glass mastering

Glass mastering is performed in a class 100 (ISO 5) or better clean room or a self-enclosed clean environment within the mastering system. Contaminants introduced during critical stages of manufacturing (eg, dust, pollen, hair, or smoke) can cause sufficient errors to make a master unusable. Once successfully completed, a CD master will be less susceptible to the effects of these contaminants.

During glass mastering, glass is used as a substrate to hold the CD master image while it is created and processed; hence the name. Glass substrates, noticeably larger than a CD, are round plates of glass approximately 240 mm in diameter and 6 mm thick. They often also have a small, steel hub on one side to facilitate handling. The substrates are created specially for CD mastering and one side is polished until it is extremely smooth. Even microscopic scratches in the glass will affect the quality of CDs pressed from the master image. The extra area on the substrate allows for easier handling of the glass master and reduces risk of damage to the pit and land structure when the "father" stamper is removed from the glass substrate.

Once the glass substrate is cleaned using detergents and ultrasonic baths, the glass is placed in a spin coater. The spin coater rinses the glass black with a solvent and then applies either photoresist or dye-polymer depending on the mastering process. Rotation spreads photoresist or dye-polymer coating evenly across the surface of the glass. The substrate is removed and baked to dry the coating and the glass substrate is ready for mastering.

Mastering is performed by a Laser Beam Recorder (LBR) machine. These use one of two recording techniques; photo resist and non-photoresist mastering. Photoresist also comes in two variations; positive photoresist and negative photoresist.

While nearly all mastering to glass is done at multiple speeds for sake of plant efficiency (8X or higher is common), **single speed glass mastering** (also referred to as **1X glass cutting** or **1x glass mastering**) is offered by a few CD replication plants as a higher quality process. A large number of audiophiles believe this results in truer reproduction[*citation needed*] although this has remained a matter of controversy for many years.

Photoresist mastering

Photoresist mastering uses a light-sensitive material (a photoresist) to create the pits and lands on the CD master blank.

The laser beam recorder uses a deep blue or ultraviolet laser to write the master. When exposed to the laser light, the photoresist undergoes a chemical reaction which hardens it. The exposed area is then soaked in a developer solution which removes the exposed positive photoresist or the unexposed negative photoresist.

Once the mastering is complete, the glass master is removed from the LBR and chemically 'developed'.

Once developing is finshed, the glass master is metalized to provide a surface for the stamper to be formed onto.

Non-photoresist (NPR) or Dye-Polymer mastering

Once the glass is ready for mastering, it is placed in a Laser Beam Recorder (LBR). Most LBRs are capable of mastering at greater than x1 speed, but due to the weight of the glass substrate and the requirements of a CD master they are typically mastered at no greater than 8X playback speed. The LBR uses a laser to write the information, with a wavelength and final lens NA (numerical aperture) chosen to produce the required pit size on the master blank. For example, DVD pits are smaller than CD pits, so a shorter wavelength or higher NA (or

the master blank. For example, DVD pits are smaller than CD pits, so a shorter wavelength or higher NA (or both) is needed for DVD mastering.

When a laser is used to record on the dye-polymer used in NPR mastering, the dye-polymer absorbs laser energy focused in a precise spot; this vapourises and forms a pit in the surface of the dye-polymer. This pit can be scanned by a red laser beam that follows the cutting beam, and the quality of the recording can be directly and immediately assessed; for instance, audio signals being recorded can also be played straight from the glass master in real time. The pit geometry and quality of the playback can all be adjusted while the CD is being mastered, as the blue writing laser and the red read laser are typically connected via a feedback system to optimise the recording. This allows the dye-polymer LBR to produce very consistent pits even if there are variations in the dye-polymer layer. Another advantage of this method is that pit depth variation can be programmed during recording to compensate for downstream characteristics of the local production process (eg, marginal molding performance). This cannot be done with photoresist mastering because the pit depth is set by the PR coating thickness, whereas dye-polymer pits are cut into a coating thicker than the intended pits.

This type of mastering is called *Direct Read After Write* or *DRAW* and is the main advantage of some non-photoresist recording systems. Problems with the quality of the glass blank master, such as scratches, or an uneven dye-polymer coating, can be immediately detected. If required the mastering can be halted, saving time and increasing, throughput.

Post-mastering

After mastering, the glass master is baked to harden the developed surface material to prepare it for metalisation. Metalisation is a critical step prior to electrogalvanic manufacture (electroplating).

The developed glass master is placed in a vapour deposition metaliser which uses a combination of mechanical vacuum pumps and cryopumps to lower the total vapour pressure inside a chamber to a hard vacuum. A piece of nickel wire is then heated in a tungsten boat to white hot temperature and the nickel vapour deposited onto the rotating glass master. The glass master is coated with the nickel vapour up to a typical thickness of around 400 nm.

The finished glass masters are inspected for stains, pinholes or incomplete coverage of the nickel coating and passed to the next step in the mastering process.

Electroforming

Electroforming occurs in "Matrix", the name used for the electroforming process area in many plants; it is also a class 100 (ISO 5) or better clean room. The data (music, computer data, etc) on the metalised glass master is extremely easy to damage and must be transferred to a tougher form for use in the injection moulding equipment which actually produces the end-procut optical disks.

The metalised master is clamped in a conductive plating frame with the data side facing outwards and lowered into a plating tank. The tank contains a nickel salt solution (usually nickel sulfamate) at a particular concentration which may be adjusted slightly in different plants depending on the characteristics of the prior steps. The solution is carefully buffered to maintain its pH, and detergents are added to maintain a specific surface tension. If the surface tension is too high, the solution cannot flow around the very small features (ie, the pits and lands) on the surface of the glass master sufficiently well to deposit metal properly. The bath is heated to approximately 40 °C.

The glass master is rotated in the plating tank while a pump circulates the plating solution over the surface of the master. As the electroforming progresses, nickel is galvanically drawn out of the solution and must be

replenished to maintain a constant concentration in the plating bath. This is achieved using high purity nickel pellets (99.99% pure) suspended in the solution in non-conductive polypropylene bags called *anode bags*. The plating solution flows through the bag and over the glass master. The anode bags stop sediment formed during the nickel decomposition from reaching the solution and perhaps being plated onto to a master's surface. The nickel is packed firmly into the bag and forms part of the electric circuit.

A DC current applied to the glass master is the source of the galvanic potential which forces nickel from the anode pellets in the bags into solution as ions and ultimately onto the master's surface as an electrically neutral metallic layer. The electrons flow in the opposite direction to the current, from the cathode to the anode via the solution. Electrons are stripped from the nickel in the anode bag, travel through the external circuit before combining with nickel ions in the solution at the cathode end thus forming metallic nickel on the surface of the glass master.

The current must start off quite low and be increased slowly and evenly to prevent the metalised surface from overheating damage. As the thickness of the nickel on the glass master increases, the current can be increased. The electroplating step is finished after approximately 1 hour. Typical stampers are 0.300 mm thick. The part is removed from the tank and the metal layer peeled off the glass substrate. The metal part, now called a "father", has the desired data as a series of bumps rather than pits; it is a negative master. The father is washed with deionised water and other chemicals such as sodium hydroxide or acetone to remove all trace of resist or other contaminants. The glass master can be sent for reclamation, cleaning and checking before reuse. If defects are detected, it will be discarded or recycled.

Once cleaned of any loose nickel and resist, the father is electrolysed, washed and clamped back into a frame and returned to the plating tank. This time the metal part that is grown is the mirror image of the father and is called a "mother"; this is a 'positive' master. All the stampers used to manufacture the CDs are made from a mother. Mothers can sometimes be regrown from fathers if they become damaged, however if handled correctly, 10 - 20 stampers can be grown from a single mother before the quality of the stamper is reduced unacceptably. Mothers are regrown from the father if it still exists, otherwise a new glass master is made.

If the CD is to be part of a long production run, the father may be archived, however it is generally cut down with a hyper-accurate hydraulic punch and used as a stamper for moulding runs. Stampers and fathers are the same (negative) "polarity", the information surface is made up of a series of bumps. Mothers are the reverse and have pits on their surfaces.

A father, mother, and a collection of stampers (sometimes called "sons") are known collectively as a "family". Fathers and mothers are the same size as a glass substrate, typically 300 µm in thickness. Stampers do not require the extra space around the outside of the program area and they are punched to remove the excess nickel from outside and inside the information area in order to fit the mould of the injection moulding machine (IMM). The physical dimensions of the mould vary somewhat from machine to machine.

Replication

CD moulding machines are specifically designed high temperature polycarbonate injection moulders. They have an average throughput of 550-900 discs per hour, per moulding line. Clear polycarbonate pellets are first dried at around 130 degrees Celsius for three hours (nominal; this depends on which optical grade resin is in use) and are fed via vacuum transport into one end of the injection moulder's barrel (ie, the feed throat) and are moved to the injection chamber via a large screw inside the barrel. The barrel, wrapped with heater bands ranging in temperature from ca 210 to 320 degrees Celsius melts the polycarbonate. When the mould is closed the screw moves forward to inject molten plastic into the mould cavity. When the mould is full, cool water running through mould halves, outside the cavity, cools the plastic so it somewhat solidifies. The entire process from the mould

closing, injection and opening again takes approximately 3 to 5 seconds.

The moulded "disc" (referred to as a 'green' disc, lacking final processing) is removed from the mould by vacuum handling; high-speed robot arms with vacuum suction caps. They are moved onto the finishing line infeed conveyor, or cooling station, in preparation for metallisation. At this point the discs are clear and contain all the digital information desired; however they cannot be played because there is no reflective layer.

The discs pass, one at a time, into the metaliser, a small chamber at approximately 10^{-3} Torr (130 mPa) vacuum. The process is called 'sputtering'. The metaliser contains a metal "target" — almost always an alloy of (mostly) aluminium and small amounts of other metals. There is a load-lock system (similar to an airlock) so the process chamber can be kept at high vacuum as the discs are exchanged. When the disc is rotated into the processing position by a swivel arm in the vacuum chamber, a small dose of argon gas is injected into the process chamber and a 700 volt DC electrical current at up to 20 kW is applied to the target. This produces a plasma from the target, and the plasma vapor is deposited onto the disc; it is an anode - cathode transfer. The metal coats the data side of the disc (upper surface), covering the pit and lands. This metal layer is the reflective surface which can be seen on the reverse (non label side) of a CD. This thin layer of metal is subject to corrosion from various contaminants and so is protected by a thin layer of lacquer.

After metalisation, the discs pass on to a spin-coater, where UV curable lacquer is dispensed onto the newly metallized layer. By rapid spinning, the lacquer coats the entire disc with a very thin layer (approx. 70 nm). After the lacquer is applied, the disks pass under a high intensity UV lamp which cures the lacquer rapidly. The lacquer also provides a surface for a label, generally screen printed or offset printed. The printing ink(s) must be chemically compatible with the lacquer used. Markers used by consumers to write on blank surfaces are not always, which can lead to breaks in the protective lacquer layer, to corrosion of the reflective layer, and failure of the CD.

Testing

For quality control, both the stamper and the moulded discs are tested before a production run. Samples of the disc (test pressings) are taken during long production runs and tested for quality consistency. Pressed discs are analyzed on a signal analysis machine. The metal stamper can also be tested on a signal analysis machine which has been specially adapted (larger diameter, more fragile, ...). The machine will "play" the disc or stamper and measure various physical and electrical parameters. Errors can be introduced at every step of production, but the moulding process is the least subject to adjustment. Error sources of errors are more readily identified and compensated for during mastering. If the errors are too severe then the stamper is rejected and a replacement installed. An experienced machine operator can interpret the report from the analysis system and optimise the moulding process to make a disc that meets the required Rainbow Book specification (e.g. Red Book for Audio from the Rainbow Books series).

If no defects are found, the CD continues to printing so a label can be screen or offset printed on the top surface of the disc. Thereafter, disks are counted, packaged, and shipped.

Multitrack recording (also known as **multitracking** or just **tracking** for short) is a method of sound recording that allows for the separate recording of multiple sound sources to create a cohesive whole. Multitracking became possible with the idea of simultaneously recording different audio channels to separate discrete "tracks" on the same tape—a "track" was simply a different channel recorded to its own discrete area on tape whereby their relative sequence of recorded events would be preserved, and playback would be simultaneous or *synchronized.*

In the 1980s and 1990s, computers provided means by which both sound recording and reproduction could be digitized, revolutionizing audio distribution. In the 2000s, multitracking hardware and software for computers was of sufficient quality to be widely used for high-end audio recording. Though tape has not been universally replaced as a recording medium, the advantages of non-linear editing and recording have resulted in digital systems largely superseding tape.

Process

Multitracking can be achieved with analogue, tape-based equipment (from simple, cassette-based four or eight trackers to 2" reel-to-reel 24-track machines), digital equipment that relies on tape storage of recorded digital data (such as ADAT eight-track machines) and hard disk-based systems often employing a computer and audio recording software. Multitrack recording devices vary in their specifications, such as the number of simultaneous tracks available for recording at any one time; in the case of tape-based systems this is limited by, among other factors, the physical size of the tape employed. Some of the biggest professional analog recording studios used a computer to synchronize multiple 24-track machines, effectively multiplying the number of available tracks into the hundreds. The rock group Toto recorded their fourth album on four computer-synced 24-track machines, for example.

For computer-based systems the trend is towards unlimited numbers of record/playback tracks, although issues such as memory and CPU available will in fact limit this from machine to machine. Moreover, on

computer-based systems, the number of simultaneously available recording tracks is limited by the sound card discrete analog or digital inputs.

When recording, audio engineers can select which track (or tracks) on the device will be used for each instrument, voice, or other input.

At any given point on the tape, any of the tracks on the recording device can be recording or playing back using sel-sync or Selective Synchronous recording. This allows an artist to be able to record onto track 2 and, simultaneously, listen to track 1, 3 and 7, allowing them to sing or to play an accompaniment to the performance already recorded on these tracks. They might then record an alternate version on track 4 while listening to the other tracks. All the tracks can then be played back in perfect synchrony, as if they had originally been played and recorded together. This can be repeated until all of the available tracks have been used, or in some cases, reused. During mix down a separate set of playback heads with higher fidelity are used.

Overview

Multitrack recording is a process in which the tape is divided into multiple tracks parallel with each other. Because they are carried on the same medium, the tracks stay in perfect synchronization. The first development in multitracking was stereo sound, which divided the recording head into two tracks. First developed by German audio engineers ca. 1943, 2-track recording was rapidly adopted for modern music in the 1950s because it enabled signals from two or more separate microphones to be recorded simultaneously, enabling stereophonic recordings to be made and edited conveniently. (The first stereo recordings, on disks, had been made in the 1930s, but were never issued commercially.) Stereo (either true, two-microphone stereo or multimixed) quickly became the norm for commercial classical recordings and radio broadcasts, although many pop music and jazz recordings continued to be issued in monophonic sound until the mid-1960s.

Much of the credit for the development of multitrack recording goes to guitarist, composer and technician Les Paul, who also helped design the famous electric guitar that bears his name. His experiments with tapes and recorders in the early 1950s led him to order the first custom-built eight-track recorder from Ampex, and his pioneering recordings with his then wife, singer Mary Ford, were the first to make use of the technique of multitracking to record separate elements of a musical piece asynchronously — that is, separate elements could be recorded at different times. Paul's technique enabled him to listen to the tracks he had already taped and record new parts in time alongside them.

Multitrack recording was immediately taken up in a limited way by Ampex, who soon produced a commercial 3-track recorder. These proved extremely useful for popular music, since they enabled backing music to be recorded on two tracks (either to allow the overdubbing of separate parts, or to create a full stereo backing track) while the third track was reserved for the lead vocalist. Three-track recorders remained in widespread commercial use until the mid-1960s and many famous pop recordings — including many of Phil Spector's so-called "Wall of Sound" productions and early Motown hits — were taped on Ampex 3-track recorders. Engineer Tom Dowd was among the first to utilize multitrack recording for popular music production while working for Atlantic Records during the 1950s.

The next important development was 4-track recording. The advent of this improved system gave recording engineers and musicians vastly greater flexibility for recording and overdubbing, and 4-track was the studio standard for most of the later 1960s. Many of the most famous recordings by The Beatles and The Rolling Stones were recorded on 4-track, and the engineers at London's Abbey Road Studios became particularly adept at a technique called "reduction mixes" in the UK and "bouncing down" in the United States, in which multiple tracks were recorded onto one 4-track machine and then mixed together and transferred (bounced down) to one track of a second 4-track machine. In this way, it was possible to record literally dozens of separate tracks and combine them into finished recordings of great complexity.

All of the Beatles classic mid-60s recordings, including the albums Revolver and Sgt Pepper's Lonely Hearts Club Band, were recorded in this way. There were limitations, however, because of the build-up of noise during the bouncing-down process, and the Abbey Road engineers are still justly famed for the ability to create dense multitrack recordings while keeping background noise to a minimum.

4-track tape also enabled the development of quadraphonic sound, in which each of the four tracks was used to simulate a complete 360-degree surround sound. A number of albums including Pink Floyd's The Dark Side of the Moon and Mike Oldfield's Tubular Bells were released both in stereo and quadrophonic format in the 1970s, but 'quad' failed to gain wide commercial acceptance. Although it is now considered a gimmick, it was the direct precursor of the surround sound technology that has become standard in many modern home theatre systems.

In a professional setting today, such as a studio, audio engineers may use 24 tracks or more for their recordings, utilizing one or more tracks for each instrument played.

The combination of the ability to edit via tape splicing, and the ability to record multiple tracks, revolutionized studio recording. It became common studio recording practice to record on multiple tracks, and mix down afterward. The convenience of tape editing and multitrack recording led to the rapid adoption of magnetic tape as the primary technology for commercial musical recordings. Although 33⅓ rpm and 45 rpm vinyl records were the dominant consumer format, recordings were customarily made first on tape, then transferred to disc, with Bing Crosby leading the way in the adoption of this method in the United States.

In both the National Television System Committee (NSTC] and Phase Alternating Line (PAL) standard video systems, video data may be transmitted as a single composite signal carrying both brightness and color information. Specifically, a composite video signal includes synchronization information, a luminance (Y) component and a chrominance or "chroma" (C) component. The C component is generated by modulating U and V color components with a color subcarrier of a given color subcarrier frequency, in which the U component is the difference between the Y component and the blue color content and the V component is difference between the Y component and the red color content.

In both the NTSC and PAL systems, frames of composite video data are transmitted as two interleaved fields of lines of display pixels. Generally, each line of pixels is transmitted as a horizontal synchronization signal, a color burst signal, and the active composite video Y and C components. The horizontal synchronization signal indicates the start of the transmission of the line and gates the following color burst signal into the color synchronization circuitry. As discussed below, the color burst signal controls the recovery of the U and V color components from the received C component during demodulation. Generally, the color burst is a sample of video data represented by the subcarrier signal, which has been modulated such that the V component has a zero (0) value and the U component has a non-zero value.

A typical composite video decoder in the receiving system includes a phase locked loop, which generates cosine and sine signals at the color subcarrier frequency for demodulating the C component of the composite video signal. Specifically, the cosine and sine signals are locked in phase and frequency to the color subcarrier frequency of color burst signal of each received line. The cosine and sine signals are locked in frequency and ninety degrees (90°) out-of-phase with respects to each other. Generally, the cosine signal demodulates the C component of the composite video signal to recover the V color component and the sine signal demodulates the C component of the composite video signal to recover the U color component, following separation of the Y and C components.

Even though the color burst signal is locked in phase within three (3) degrees of phase of the locally generated sine signal, the remaining three (3) degrees of phase error still introduces anomalies in the ultimate video display. For example, in NTSC systems, phase error between the color burst signal and the locally generated sine signal, and hence the associated cosine signal as well, can cause a constant color shift in the video display. In PAL systems, this phase error can result in unwanted line-to-line patterns known as "Hanover Bars" in the video display.

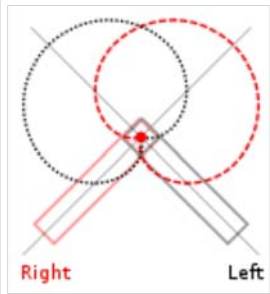
In the past, video systems processing composite video signals have generally addressed the problem of phase error between the color burst signal and the locally generated cosine and sine signals by averaging equal contributions of chrominance data for even and odd display lines. These existing techniques, however, are only applicable for processing constant color display regions and desaturate the U and V components.

Hence, in order to minimize anomalies in the video display systems operating on composite video, new techniques are required for addressing the problem of phase error between a received color burst signal and the local cosine and sine signals required for color component recovery. These techniques should be applicable to both NTSC and PAL standard systems, although not necessarily limited thereto.

Recording methods

X-Y technique: intensity stereophony

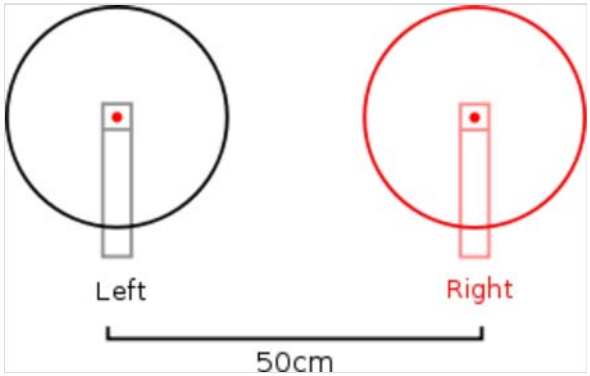
Here, two directional microphones are at the same place, typically pointing at an angle between 90° and 135° to each other (see also "The Stereophonic Zoom" by Michael Williams). The stereo effect is achieved through differences in sound pressure level between two microphones. A difference in levels of 18 dB (16 to 20 dB) is needed for hearing the direction of a loudspeaker. Due to the lack of differences in time-of-arrival/phase ambiguities, the sonic characteristic of X-Y recordings has less sense of space and depth when compared to recordings employing an A-B setup. When two figure-eight microphones are used, facing ±45° with respect to the sound source, the X-Y setup is called a Blumlein Pair. The sonic image produced is realistic, almost "holographic". (See also acoustic intensity).



X-Y stereo microphone placement.

A-B technique: time-of-arrival stereophony

This uses two parallel omnidirectional microphones some distance apart, capturing time-of-arrival stereo information as well as some level (amplitude) difference information —especially if employed in close proximity to the sound source(s). At a distance of about 60 cm (0.6 m), the time delay (time-of-arrival difference) for a signal reaching the first microphone and then the other one from the side is approximately 1.5 msec (1 to 2 msec). If you increase the distance between the microphones, you effectively decrease the pickup angle. At a 70 cm distance, it is approximately equivalent to the pickup angle of the near-coincident ORTF setup.

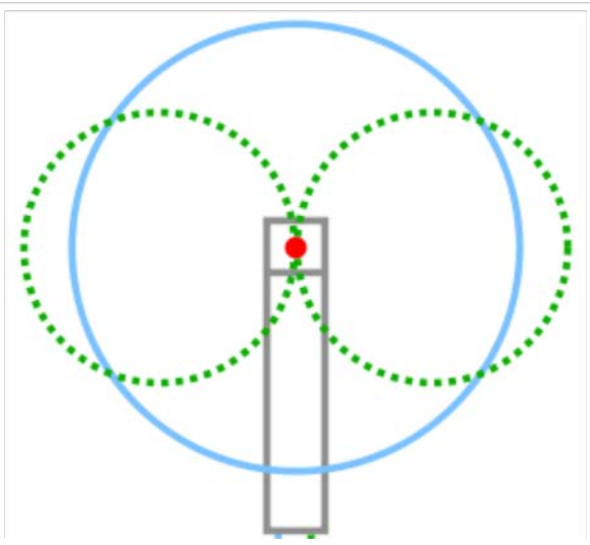


A-B stereo microphone placement.

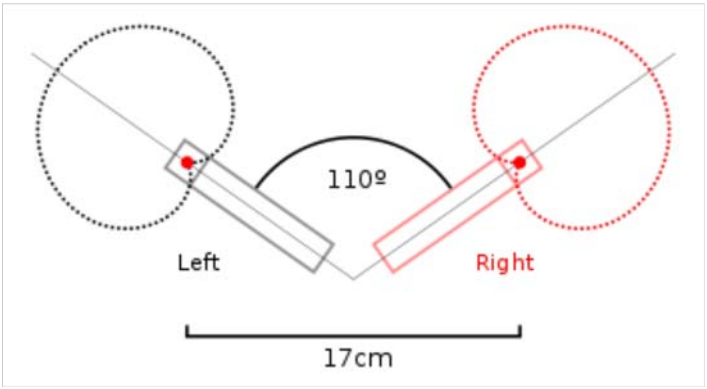
This technique can produce phase issues when the stereo signal is mixed to mono.

M/S technique: Mid/Side stereophony

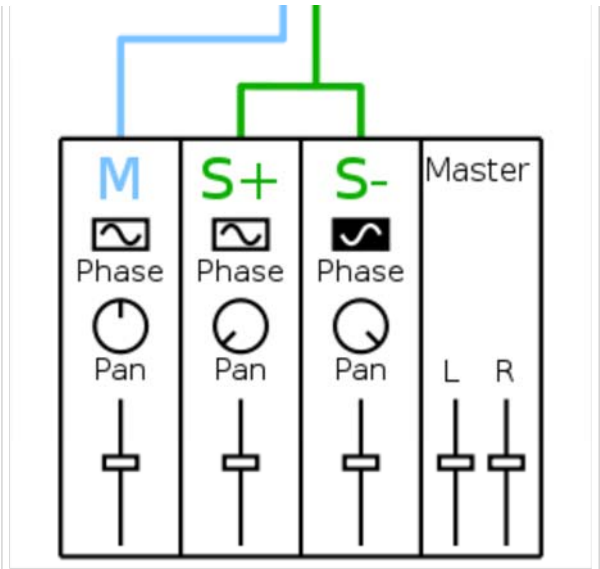
This coincident technique employs a bidirectional microphone facing sideways and another microphone (generally a variety of cardioid, although Alan Blumlein described the usage of an omnidirectional transducer in his original patent) at an angle of 90°, facing the sound source. The left and right channels are produced through a simple matrix: Left = Mid + Side; Right = Mid − Side (the polarity-reversed side signal). This configuration produces a completely mono-compatible signal and, if the Mid and Side signals are recorded (rather than the matrixed Left and Right), the stereo width can be manipulated after the recording has taken place. This makes it especially useful for film-based projects.



Near-coincident technique: mixed stereophony



ORTF stereo microphone technique.



Mid-Side stereo microphone technique.

These techniques combine the principles of both A-B and X-Y (coincident pair) techniques. For example, the ORTF stereo technique of the Office de Radiodiffusion Télévision Française (Radio France) calls for a pair of cardioid microphones placed 17 cm apart at a total angle between microphones of 110°, which results in a stereophonic pickup angle of 96° (*Stereo Recording Angle*, or SRA).[3] In the NOS stereo technique of the Nederlandse Omroep Stichting (Holland Radio), the total angle between microphones is 90° and the distance is 30 cm, thus capturing time-of-arrival stereo information as well as level information. It is noteworthy that the spacing of 17 cm has nothing to do with human ear distance. The recorded signals are generally intended for playback over stereo loudspeakers, not earphones.

Pseudo-stereo

In the course of restoration or remastering of monophonic records, various techniques of "pseudo-stereo", "quasi-stereo", or "rechanneled stereo" have been used to create the impression that the sound was originally recorded in stereo. These techniques first involved hardware methods (see Duophonic) or, more recently, a combination of hardware and software. Multitrack Studio, from Bremmers Audio Design (The Netherlands),[4] uses special filters to achieve a pseudo-stereo effect: the "shelve" filter directs low frequencies to the left channel and high frequencies to the right channel, and the "comb" filter adds a small delay in signal timing between the two channels, a delay barely noticeable by ear (the comb filter allows range of manipulation between 0 and 100 milliseconds), but contributing to an effect of "widening" original "fattiness" of mono recording.[5][6]

The special pseudo-stereo circuit—invented by Kishii and Noro, from Japan—was patented in the United States in 2003,[7] with already previously issued patents for similar devices.[8] Artificial stereo techniques have been used to improve the listening experience of monophonic recordings or to make them more "saleable" in today's market, where people expect stereo. Some critics have expressed concern about the use of these methods.[9]

Principles of analogue television

From Wikipedia, the free encyclopedia

Until the advent of digital television and flat panel displays in the 1990s, all television was based on the transmission and reception of analog signals, displayed on a cathode-ray tube. Although a number of different broadcast television systems were in use worldwide, the same principles of operation apply.

The first analog television systems were monochrome; they were enhanced to include color beginning in the 1960s (see article History of television).

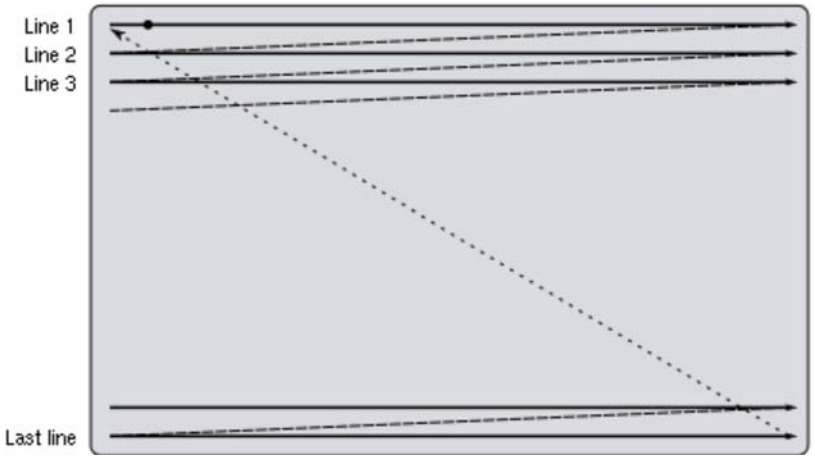
Contents

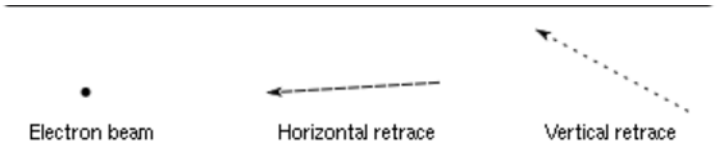
- 1 Displaying a picture
- 2 Components of a television system
  - 2.1 Receiving the signal
  - 2.2 Picture and Synchronisation
  - 2.3 Synchronisation
  - 2.4 Monochrome video
  - 2.5 Power Supply
- 3 Color video
- 4 See also
- 5 References
- 6 External links

Displaying a picture

A CRT television displays an image by scanning a beam of electrons across the screen in a pattern of horizontal lines known as a raster. At the end of each line the beam returns to the start of the next line; at the end of the last line it returns to the top of the screen. As it passes each point the intensity of the beam is varied, varying the brightness (technically, luminance) of that point. A color television system is identical except that an additional signal known as chrominance controls the color of the spot.

Raster scanning is shown in a slightly simplified form below.





When analog television was developed, no affordable technology for storing any video signals existed; the luminance signal has to be generated and transmitted at exactly the point in time at which is displayed on the CRT. It is therefore essential to keep the raster scanning in the camera (or other device for producing the signal) in exact synchronization with the scanning in the television.

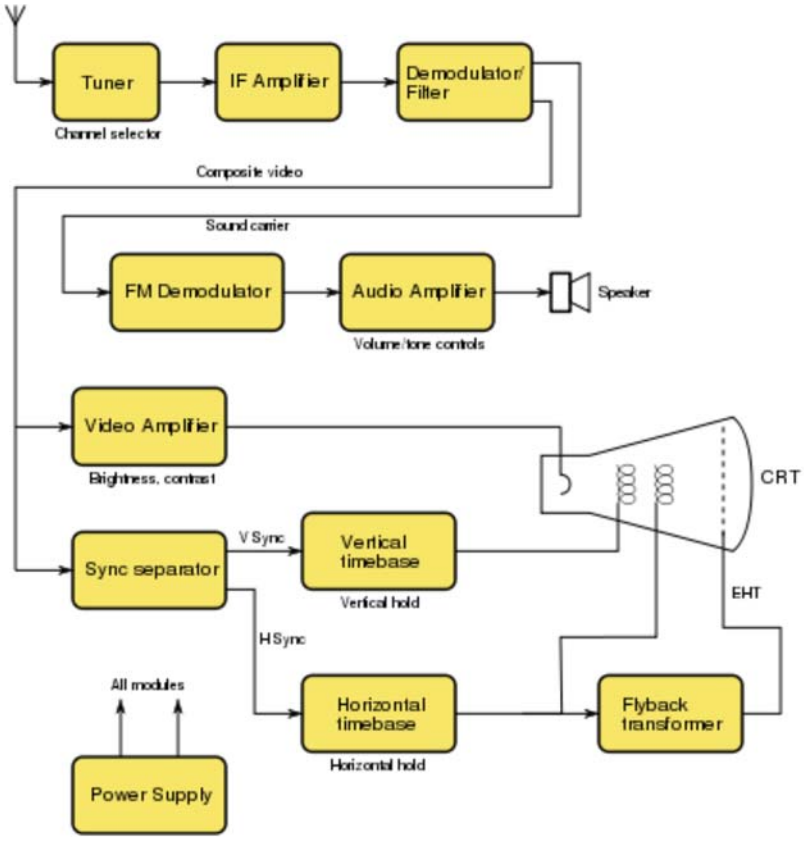
The physics of the CRT require that a finite time interval is allowed for the spot to move back to the start of the next line (*horizontal retrace*) or the start of the screen (*vertical retrace*). The timing of the luminance signal must allow for this.

Raster scanning has to be performed sufficiently quickly that persistence of vision allows the eye to view a stable image, and such that moving images can be displayed without appearing jerky. The maximum frame rate achievable depends on the bandwidth of the electronics and transmission system, and the number of lines in the image. In practice, a rate of 50 or 60 hertz is a satisfactory compromise, with interlacing used to double the apparent number of lines.

Components of a television system

A practical television system needs to take luminance, chrominance (in a color system), synchronization (horizontal and vertical), and audio signals, and broadcast them over a radio transmission. The transmission system must include a means of channel selection.

A typical analog television receiver is based around the block diagram shown below:



Receiving the signal

The television system for each country will specify a number of *channels* within the UHF or VHF frequency ranges. A channel actually consists of two signals: the picture information is transmitted using amplitude modulation on one frequency, and the sound is transmitted with frequency modulation at a frequency at a fixed offset (typically 4.5 to 6MHz) from the picture signal.

The channel frequencies chosen represent a compromise between allowing enough bandwidth for video (and hence satisfactory picture resolution), and allowing enough channels to be packed into the available frequency band. In practice a technique called vestigial sideband is used to reduce the channel spacing, which would be at least twice the video bandwidth if purely AM was used.

Signal reception is invariably done via a superhet receiver: the first stage is a *tuner* which selects a channel and frequency-shifts it to a fixed intermediate frequency (IF). Signal amplification (from the microvolt range to fractions of a volt) is then performed largely by the IF stages.

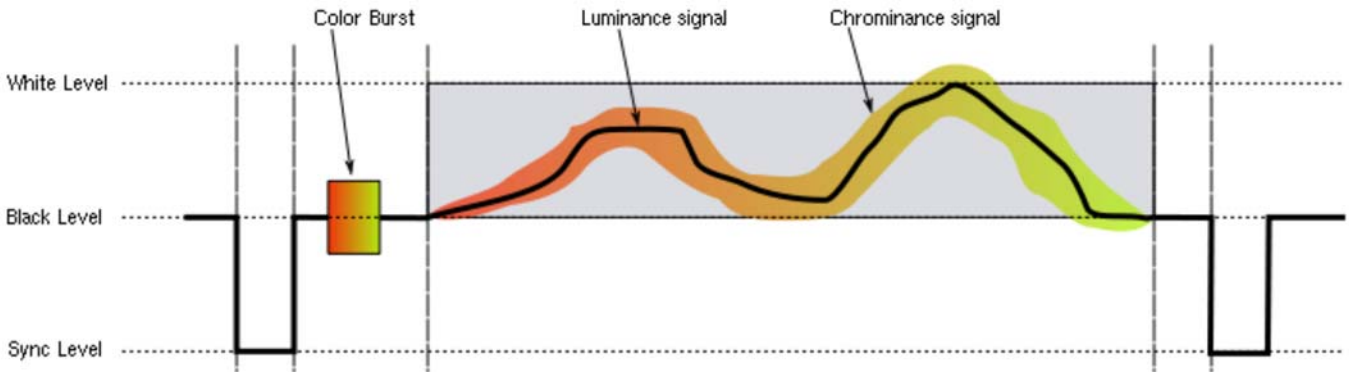
At this point the IF signal consists of a video carrier at one frequency and the sound carrier at a fixed offset. Early systems would feed this to a simple demodulator, which produced a video signal at baseband and the sound as an FM signal at the offset frequency (this is known as *intercarrier sound*). Later systems filter the IF first to prevent interference between sound and vision.

The FM sound carrier is then demodulated, amplified, and used to drive a loudspeaker. Until the advent of NICAM sound transmission was invariably monophonic.

Picture and Synchronisation

The video carrier is demodulated to give a composite video signal; this contains luminance (brightness), chrominance (color) and synchronisation signals; this is identical to the video signal format used by analog video devices such as VCRs or CCTV cameras. Note that the RF signal modulation is inverted compared to the conventional AM: the minimum video signal level corresponds to maximum carrier amplitude, and vice versa. The carrier is never shut off altogether; this is to ensure that intercarrier sound demodulation can still occur.

Each line of the displayed image is transmitted using a signal as shown below. The same basic format (with minor differences mainly related to timing and the encoding of color) is used for PAL, NTSC and SECAM television systems. A monochrome signal is identical to a color one, with the exception that the elements shown in color in the diagram (the color burst, and the chrominance signal) are not present.



Synchronisation

See also: Analogue television synchronization

Synchronisation is transmitted via negative-going pulses; in a composite video signal these are approximately 0.3V below the "black level". The *horizontal sync* signal is a single short pulse which indicates the start of every line. Two timing intervals are defined - the *front porch* between the end of displayed video and the start of the sync pulse, and the *back porch* after the sync pulse and before displayed video. These and the sync pulse itself are called the *horizontal blanking* (or *retrace*) *interval* and represent the time that the electron beam in the CRT is returning to the start of the next display line.

The *vertical sync* signal is a series of much longer pulses, indicating the start of a new field. The sync pulses occupy the whole of line interval of a number of lines at the beginning and end of a scan; no picture information is transmitted during vertical retrace. The pulse sequence is designed to allow horizontal sync to continue during vertical retrace; it also indicates whether each field represents even or odd lines in interlaced systems (depending on whether it begins at the start of a horizontal line, or mid-way through).

In the TV receiver, a *sync separator* circuit detects the sync voltage levels and sorts the pulses into horizontal and vertical sync. These are fed to horizontal and vertical *timebase* circuits which generate sawtooth current waveforms, which are each reset by the appropriate sync pulse. These waveforms are fed to the horizontal and vertical *scan coils* wrapped around the CRT tube. These produce a magnetic field proportional to the changing current, and this deflects the electron beam, scanning it across the tube surface.

The lack of precision timing components available in early television receivers meant that the timebase circuits occasionally needed manual adjustment. The adjustment took the form of *horizontal hold* and *vertical hold* controls, usually on the rear of the set. Loss of horizontal synchronisation usually resulted in an unwatchable picture; loss of vertical synchronisation would produce an image rolling up or down the screen.

Monochrome video

The luminance component of a composite video signal varies between 0V and approximately 0.7V above the 'black' level. (In the NTSC system, there is in fact a *blanking* signal level used during the front porch and back porch, and a *black* signal level 75mV above it; in PAL and SECAM these are identical).

In a monochrome receiver the luminance signal is simply amplified (with brightness and contrast controls determining DC shift and amplification, respectively) and used to drive the control grid in the electron gun of the CRT. This changes the intensity of the electron beam and therefore the brightness of the spot being scanned.

Power Supply

Most of the receiver's circuitry (at least in Transistor or IC based designs) operates from a comparatively low-voltage DC power supply. However, the anode connection requires a very high voltage (typically 10-30kV) for correct operation.

This voltage is not generally produced by the main power supply circuitry; instead the receiver makes use of the circuitry used for horizontal scanning. At the end of each horizontal scan line, the magnetic field which has built up in the scan coils contains electromagnetic energy. This must be dissipated when the field is reversed during horizontal

retrace. Instead of being dissipated as waste heat, the horizontal scan coil is discharged into the primary winding of a flyback transformer. The secondary of this is fed to a high-voltage rectifier which produces the required EHT supply (see flyback converter for a detailed description of this form of power supply).

Typically, the flyback transformer and rectifier circuitry are incorporated into a single unit with a captive output lead, so that all high-voltage parts are enclosed. The high frequency (15Khz or so) of the horizontal scanning allows reasonably small components to be used.

Color video

A color signal conveys picture information for each of the red, green, and blue components of an image (see the article on Color space for more information). However, these are not simply transmitted as three separate signals, because:

- such a signal would not be compatible with monochrome receivers (an important consideration when color broadcasting was first introduced)
- it would occupy three times the bandwidth of existing television, requiring a decrease in the number of channels available
- typical problems with signal transmission (such as differing received signal levels between different colors) would produce unpleasant side-effects.

Instead, the RGB signals are converted into YUV form, where the Y signal represents the overall brightness, and can be transmitted as the luminance signal. This ensures a monochrome receiver will display a correct picture. The U and V signals are the difference between the Y signal and the B and R signals respectively. The U signal then represents how 'blue' the color is, and the V signal how 'red' it is. The advantage of this scheme is that the U and V signals are zero when the picture has no color content. As the eye is more sensitive to errors in luminance than in color, the U and V signals can be transmitted in a relatively lossy (specifically: bandwidth-limited) way with acceptable results. The G signal is not transmitted in the YUV system but is recovered algebraically at the receiving end.

In the NTSC and PAL color systems, U and V are transmitted by adding a *color subcarrier* to the composite video signal, and using quadrature amplitude modulation on it. In NTSC, the subcarrier is at approximately 3.58 MHz, in PAL it is roughly 4.43 MHz - these frequencies are within the luminance signal band, but the exact frequency is chosen so that it is midway between two harmonics of the line repetition rate, thus ensuring that the majority of the energy of the luminance signal does not overlap with the energy of the chroma signal.

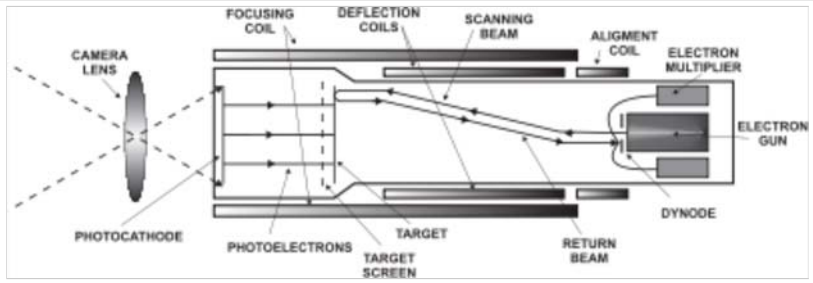
The two signals (U and V) modulate both the amplitude and phase of the color carrier, so to demodulate them it is necessary to have a reference signal against which to compare it. For this reason a short burst of reference signal known as the *color burst* is transmitted during the back porch of each line. A reference oscillator in the receiver locks onto this signal (see phase-locked loop) to achieve a phase reference, and uses its amplitude to set an AGC system to achieve an amplitude reference.

The U and V signals are then demodulated by band-pass filtering to retrieve the color subcarrier, mixing it with the in-phase and quadrature signals from the reference oscillator, and low-pass filtering the results.

NTSC uses this process unmodified; unfortunately this often results in poor color reproduction due to phase errors in the received signal. The PAL system corrects this by reversing the phase of the signal on each successive line and averaging the result over pairs of lines. Phase errors therefore tend to be cancelled out.

In the SECAM television system, U and V are transmitted on *alternate* lines, using simple frequency modulation of the color subcarrier.

Image orthicon



Schematic of image orthicon tube.

The image orthicon, (sometimes abbreviated IO) was common in American broadcasting from 1946 until 1968.[80] A combination of the image dissector and the orthicon technologies, it replaced the iconoscope and the orthicon, which required a great deal of light to work adequately.[*citation needed*]

The image orthicon tube was developed at RCA by Albert Rose, Paul K. Weimer, and Harold B. Law. It represented a considerable advance in the television field, and after further development work, RCA created original models between 1939 and 1940.[81] The National Defense Research Council entered into a contract with RCA where the NDRC paid for its further development. Upon RCA's development of the more sensitive image orthicon tube in 1943, RCA entered into a production contract with the U.S. Navy, the first tubes being delivered in January 1944.[82] RCA began production of image orthicons for civilian use in the second quarter of 1946.[52]

While the iconoscope and the intermediate orthicon used capacitance between a multitude of small but discrete light sensitive collectors and an isolated signal plate for reading video information, the image orthicon employed direct charge readings from a continuous *electronically charged* collector. The resultant signal was immune to most extraneous signal "crosstalk" from other parts of the target, and could yield extremely detailed images. For instance, image orthicon cameras were used for capturing Apollo/Saturn rockets nearing orbit after the networks had phased them out, as only they could provide sufficient detail.[*citation needed*]

An image orthicon camera can take television pictures by candlelight because of the more ordered light-sensitive area and the presence of an electron multiplier at the base of the tube, which operated as a high-efficiency amplifier. It also has a logarithmic light sensitivity curve similar to the human eye. However, it tends to flare in bright light, causing a dark halo to be seen around the object; this anomaly is referred to as "blooming" in the broadcast industry when image orthicon tubes were in operation.[*citation needed*] Image orthicons were used extensively in the early color television cameras, where their increased sensitivity was essential to overcome their very inefficient optical system.[*citation needed*]

Operation

An image orthicon consists of three parts: a photocathode with an image store ("*target*"), a scanner that reads this image (an electron gun), and a multistage electron multiplier.[*citation needed*]

In the image store, light falls upon the photocathode which is a photosensitive plate at a very negative potential (approx. -600V), and is converted into an electron image (a principle borrowed from the image dissector). This electron *rain* is then accelerated towards the target (a very thin glass plate acting as a semi-isolator) at ground potential (0V), and passes through a very fine wire mesh (near 200 wires per cm), very near (a few hundredths of cm) and parallel to the target, acting as a screen grid at a slightly positive voltage (approx +2V). Once the image electrons reach the target, they cause a "splash" of electrons by the effect of secondary emission. On average, each image electron ejects several "splash" electrons (thus adding amplification by secondary emission), and these excess electrons are soaked up by the positive mesh effectively removing electrons from the target and causing a positive charge on it in relation to the incident light in the photocathode. The result is an image painted in positive charge, with the brightest portions having the largest positive charge.[*citation needed*]

image painted in positive charge, with the brightest portions having the largest positive charge.

A sharply focused beam of electrons (a cathode ray) is generated by the electron gun at ground potential and accelerated by the anode (the first dynode of the electron multiplier) around the gun at a high positive voltage (approx. +1500V). Once it exits the electron gun, its inertia makes the beam move away from the dynode towards the back side of the target. At this point the electrons lose speed and get deflected by the horizontal and vertical deflection coils, effectively scanning the target. Thanks to the axial magnetic field of the focusing coil, this deflection is not in a straight line, thus when the electrons reach the target they do so perpendicularly avoiding a sideways component. The target is nearly at ground potential with a small positive charge, thus when the electrons reach the target at low speed they are absorbed without ejecting more electrons. This adds negative charge to the positive charge until the region being scanned reaches some threshold negative charge, at which point the scanning electrons are reflected by the negative potential rather than absorbed (in this process the target recovers the electrons needed for the next scan). These reflected electrons return down the cathode ray tube toward the first dynode of the electron multiplier surrounding the electron gun which is at high potential. The number of reflected electrons is a linear measure of the target's original positive charge, which, in turn, is a measure of brightness.[*citation needed*]

Additional amplification is also performed via secondary emission in the electron multiplier which consists of a stack of charged dynodes (pinwheel-like disks surrounding the electron gun) in progressively higher potentials. As the returning electron beam hits the first dynode, it ejects electrons similarly to the target; for each electron striking a dynode, many are emitted. These secondary electrons are then drawn toward the next dynode at a higher potential, where the splashing continues for a number of steps. Consider a single, highly-energized electron hitting the first dynode, causing, say, four electrons to be emitted and drawn towards the next dynode. Each of these might then cause four each to be emitted. Thus, by the start of the third stage, you would have about 16 electrons to the original one. As many as 5 to 10 stages were not unusual, thus the achieved amplification is very important.[*citation needed*]

Overall, the amplification at the image front and at the electron multiplier, plus the wise use of secondary emission wherever possible make the Image Orthicon an excellent camera tube, with a typical illumination on photocathode for maximum signal output of 0.01ft-c (0.1lx). This makes it on the order of a thousand times more sensitive than the iconoscope.[*citation needed*]

Dark halo

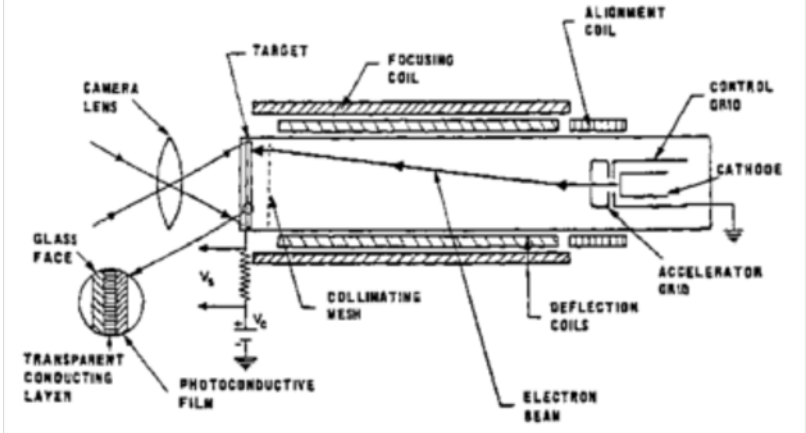
The mysterious "dark halo" around bright objects in an IO-captured image is based in the very fact that the IO relies on the splashing caused by highly energized electrons. When a very bright point of light (and therefore very strong electron stream emitted by the photosensitive plate) is captured, a great preponderance of electrons is ejected from the image target. So many are ejected that the corresponding point on the collection mesh *can no longer soak them up*, and thus they fall back to nearby spots on the target much as splashing water when a rock is thrown in forms a ring. Since the resultant splashed electrons do not contain sufficient energy to eject enough electrons where they land, they will instead neutralize any positive charge in that region. Since darker images result in less positive charge on the target, the excess electrons deposited by the splash will be read as a *dark* region by the scanning electron beam.[*citation needed*]

This effect was actually "cultivated" by tube manufacturers to a certain extent, as a small, carefully-controlled amount of the dark halo has the effect of "crispening" the viewed image. (That is, giving the illusion of being more sharply-focused than it actually is). The later Vidicon tube and its descendants (see below) do not exhibit this effect, and so could not be used for broadcast purposes until special "detail correction" circuitry could be developed.[*citation needed*]

Vidicon

A vidicon tube is a video camera tube design in which the target material is a photoconductor. The Vidicon was developed in the 1950s at RCA by P. K. Weimer, S. V. Forgue and R. R. Goodrich as a simple alternative to the structurally and electrically complex Image Orthicon.[*citation needed*] While the initial photoconductor used was selenium, other targets–including silicon diode arrays–have been used.[*citation needed*]

The vidicon is a storage-type camera tube in which a charge-density pattern is formed by the imaged scene radiation on a photoconductive surface which is then scanned by a beam of low-velocity electrons. The fluctuating voltage coupled out to a video amplifier can be used to reproduce the scene being imaged. The electrical charge produced by an image will remain in the face plate until it is scanned or until the charge dissipates. Pyroelectric photocathodes can be used to produce a vidicon sensitive over a broad portion of the infrared spectrum.[*citation needed*]



Schematic of vidicon tube.

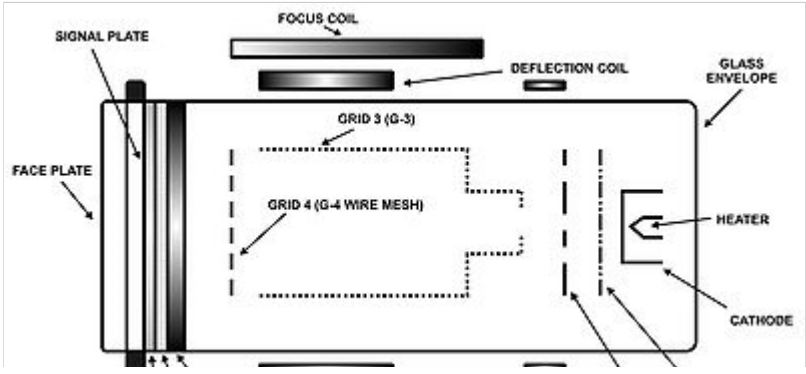
Prior to the design and construction of the Galileo probe to Jupiter in the late 70s, NASA used Vidicon cameras on most of their unmanned deep space probes equipped with the remote sensing ability.[*citation needed*]

Vidicon tubes are notable for a particular type of interference they suffered from, known as vidicon microphony. Since the sensing surface is quite thin, it is possible to bend it with loud noises. The artifact is characterized by a series of many horizontal bars evident in any footage (mostly pre 1990) in an environment where loud noise was present at the time of recording or broadcast. A studio where a loud rock band was performing or even gunshots or explosions would create this artifact.[*citation needed*]

Plumbicon

Plumbicon is a registered trademark of Philips for its Lead Oxide (PbO) target vidicons. Used frequently in broadcast camera applications, these tubes have low output, but a high signal-to-noise ratio. They had excellent resolution compared to Image Orthicons, but lacked the artificially sharp edges of IO tubes, which caused some of the viewing audience to perceive them as softer. CBS Labs invented the first outboard edge enhancement circuits to sharpen the edges of Plumbicon generated images.[83] [84] [85]

Compared to Saticons, Plumbicons had much higher resistance to burn in, and comet and trailing artifacts from bright lights in the shot. Saticons though, usually had slightly higher resolution. After 1980, and the introduction of the diode gun plumbicon tube, the resolution of both types was so high, compared to the maximum limits of the broadcasting standard, that the Saticon's resolution advantage became moot. While



broadcast cameras migrated to solid state Charged Coupled Devices, plumbicon tubes remain a staple imaging device in the medical field.[83][84][85]

Schematic of a Plumbicon tube. (This image is schematic, not to scale; a Plumbicon has the same shape as a vidicon.)

Narragansett Imaging is the only company now making Plumbicons, and it does so from the factories Philips built for that purpose in Rhode Island, USA. While still a part of the Philips empire, the company purchased EEV's (English Electric Valve) lead oxide camera tube business, and gained a monopoly in lead oxide tube production.[83][84][85]

Saticon

Saticon is a registered trademark of Hitachi also produced by Thomson and Sony. Its surface consists of Selenium Arsenic Tellurium (SeAsTe).[*citation needed*]

Pasecon

Pasecon is a registered trademark of Heimann. Its surface consists of Cadmium Selenide (CdSe).[*citation needed*]

Newvicon

Newvicon is a registered trademark of Matsushita. The Newvicon tubes were characterized by high light sensitivity. Its surface consists of a combination of Zinc Selenide (ZnSe) and Zinc Cadmium Telluride (ZnCdTe). [*citation needed*]

Trinicon

Trinicon is a registered trademark of Sony. It uses a vertically striped RGB color filter over the faceplate of an otherwise standard vidicon imaging tube to segment the scan into corresponding red, green and blue segments. Only one tube was used in the camera, instead of a tube for each color, as was standard for color cameras used in television broadcasting. It is used mostly in low-end consumer cameras and camcorders, though Sony also used it in some moderate cost professional cameras in the 1980s, such as the DXC-1800 and BVP-1 models.[86]

Although the idea of using color stripe filters over the target was not new, the Trinicon was the only tube to use the primary RGB colors. This necessitated the addition of an additional electrode buried in the target to detect where the scanning electron beam was relative to the stripe filter. Previous color stripe systems had used colors where the color circuitry was able to separate the colors purely from the relative amplitudes of the signals. As a result the Trinicon featured a larger dynamic range of operation.

Light Biasing

All the vidicon type tubes except the vidicon itself were able to use a light biasing technique to improve the sensitivity and contrast. The photosensitive target in these tubes suffered from the limitation that the light level had to rise to a particular level before any video output resulted. Light biasing was a method whereby the photosensitive target was illuminated from a light source just enough that no appreciable output was obtained, but such that a slight increase in light level from the scene was enough to provide discernible output. The light came from either an illuminator mounted around the target, or in more professional cameras from a light source on the base of the tube and guided to the target by light piping. The technique would not work with the baseline vidicon tube because it suffered from the limitation that as the target was fundamentally an insulator, the